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Type Ia Supernovae: Explosion Models versus Observational Constraints

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To have confidence in using Type Ia supernovae (SNe Ia) to determine the expansion history of the universe, and thereby probe the nature of the dark energy, we must advance our understanding of SN Ia physics. In the standard model a carbon–oxygen white dwarf accretes matter from a companion star, approaches the Chandrasekhar mass, ignites carbon fusion, encounters a thermonuclear instability, and explodes completely. The final kinetic energy of the ejected matter is the energy released by fusion minus the white–dwarf binding energy. The kinetic energy inferred from observations indicates that practically the whole white dwarf undergoes fusion. The peak luminosity depends on the mass of freshly synthesized ^{56}Ni, which provides a delayed release of energy while decaying through ^{56}Co to stable ^{56}Fe. The observed SN Ia luminosity requires that nearly half of the mass is synthesized to ^{56}Ni. Spectroscopic observations indicate that the composition structure of the ejected matter is radially stratified, with a core of iron–group elements surrounded by lighter elements such as calcium, silicon, and oxygen. Spherically symmetric (1D) nuclear-hydrodynamical explosion models that meet these requirements have been calculated, by parameterizing the velocity of the burning front. In recent years more self–consistent 3D models have been calculated. Deflagration models, in which the burning front remains subsonic, undergo insufficient fusion and lack the stratified composition structure. Delayed–detonation models, which invoke a transition to supersonic front propagation, fare better, although it is not known whether the transition really can occur. I will discuss the status of explosion models versus observational constraints (mostly spectroscopic), and the challenging task of relating the various observational manifestations of SN Ia diversity to their physical causes.